silica. One paper reported on the vestige of a Pleistocene thermal activity in Iceland.

As in the transactions of 1934, the annual reports submitted to the Section of Hydrology from its nine permanent research committees comprise significant digests of progress and development in investigations on snow, glaciers, evaporation, absorption and transpiration (including extended list of terms and definitions), rainfall and runoff (with five appendices of experimental studies and results), soil-moisture, underground water (with two appendices on the relations with oil fields and on active projects in California, Oregon and Washington), dynamics of streams and chemistry of natural waters. Nineteen papers and reports cover many diverse fields of hydrological research, both experimental and theoretical; they serve to emphasize the wide-spread activity in hydrology in the United States and the need for further support by state and government in this field. Three meetings of the section were held.

As in previous years the proceedings of the meetings of the Union have been edited by the general secretary for publication by the offset method. These "Transactions" will be in two parts. Part I (364 pages) will include papers and reports given at the General Assembly and at the meetings of the sections of Geodesy, Seismology, Meteorology, Terrestrial Magnetism and Electricity, Oceanography and Volcanology. Part II (165 pages) will include papers and reports submitted to the Section of Hydrology. The many requests being received from geophysicists in all parts of the world evidence the value of the "Transactions" in disseminating the progress of work done in America and in forwarding that international exchange of data and thought so essential to the science of geophysics and its steadily growing interpretation, utilization and application.

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*General Secretary*

WASHINGTON, D. C.

# SPECIAL ARTICLES

## A CURVE OF EXPERIMENTAL EXTINCTION IN THE WHITE RAT

PSYCHOLOGICAL studies present many examples of curves which show the progress of forgetting as a function of the time which has elapsed since learning was completed. There are, however, very few graphic representations showing the progress of the experimental extinction of a conditioned response as a function of the time which has elapsed since the completion of conditioning.

Kleitman and Crisler[1] present extinction curves, parabolic in form, for the salivary reflexes of three dogs. The curves show a decrease in the quantity of secretion, with an increase in elapsed time. Skinner[2] has studied extinction in the rat under conditions where food is the reinforcing agent and where the frequency of response is determined by the rat and not by the apparatus, as is usually the case. An inspection of his curves indicates that there is a progressive wave-like decrease in the frequency of the conditioned response during a one-hour period when no reinforcement is given. Switzer,[3] in a study of the galvanic skin reflex (GSR), studied the progress of experimental extinction to the point where two or three conditioned stimulations failed to elicit the conditioned response. The extinction curve is presented in the form of a Vincent curve, showing the decrease in the magnitude of the GSR in successive tenths of the extinction period. This curve is essentially linear, and therefore differs markedly from the curve of Kleitman and Crisler and also from such typical forgetting curves as those of Ebbinghaus and Ballard for verbal responses. It should be pointed out, however, that the usual forgetting curves (and those of Kleitman and Crisler and of Skinner) are not Vincent curves representing the amount forgotten, or eliminated, during successive equal parts of the total forgetting time; rather the usual forgetting curves represent the average amount of retention (or elimination) after selected periods of elapsed time. Further note should be made of the fact that Piéron[4] holds the sudden initial drop in the Ebbinghaus curve to be an artifact. Hilgard and Marquis,[5] working with the conditioned eyelid response in the dog, found that the frequency and amplitude of the response decreased during experimental extinction. The percentage frequency of response plotted against time gives a gradual almost linear decrease of frequency.

Although Hull[6] cautions against identifying forgetting and experimental extinction, nevertheless something can be said for an attempt to relate these

[1] N. Kleitman and G. Crisler, *Amer. Jour. Physiol.*, 79: 571–614, 1927.

[2] B. F. Skinner, *Jour. Gen. Psychol.*, 8: 114–129, 1933.

[3] St. C. A. Switzer, *Jour. Gen. Psychol.*, 9: 77–100, 1933.

[4] H. Piéron, *L'année psychol.*, 19: 91–193, 1913.

[5] E. R. Hilgard and D. G. Marquis, *Jour. Comp. Psychol.*, 19: 29–58, 1935.

[6] C. L. Hull, "Learning: the factor of the conditioned reflex," in "Handbook of general experimental psychology," p. 438. Worcester, Mass.: Clark University Press, 1934.

two phenomena. (Thus my own work[7] reveals a correlation between conditioning and extinction of the same order as that found between the learning and forgetting of verbal responses.) To what extent the underlying process in extinction and forgetting is the same remains to be determined. The two phenomena are produced under (or by) different experimental conditions, and yet each represents a progressive loss in the capacity to respond, a loss which can not be accounted for by such factors as fatigue. It is a worthy hypothesis that during the extinction period the subject is essentially learning *not* to respond to the conditioned stimulus. The relative incompleteness of this learning, plus the great prepotency of the unconditioned response, would then offer a basis for the "spontaneous" recovery of the conditioned response. Such a hypothesis is not contradictory to the view that experimental extinction is an inhibitory process; and the hypothesis is in harmony with the view, currently held in much favor, that forgetting is a result of activity interpolated between the end of the learning period and the beginning of the retest period.

The present experiment was carried out on 21 previously untrained white rats. These animals, blinded 24 hours prior to the experiment, were conditioned to run in response to a buzzer. The apparatus used and the general procedure are outlined in an earlier issue of this journal,[8] and a more detailed description of experimental conditions is given elsewhere.[7] The general procedure was to present the buzzer once per minute, followed 2 seconds later by an induction shock *unless* the animal responded to the buzzer by running approximately a distance of 4 inches. The response might be greater than this, but smaller responses were not recorded, since they were usually mere twitches of the animal's body. A record was kept of the approximate distance that the animal ran to each buzzer stimulus during conditioning and extinction. An examination of these records indicates that the responses rarely exceeded a distance of 8 inches. The usual run was about 4 inches, enough to take the animal from one grill to another in the apparatus. Occasionally a run clear around the circular apparatus, some 32 inches, was made. During conditioning and extinction there was no progressive change in the magnitude of the runs.

The sequence of buzzer and (possible) shock was continued until the rat had made at least a 4-inch response for 10 successive presentations of the buzzer. (With the method here used, this would mean 10 conditioned responses without reinforcement.) The buzzer then continued to be sounded, without reinforcement at any time, until the rat failed to make an adequate response for 5 successive stimulations, at which time the arbitrarily set standard of extinction was reached. The total period of extinction thus extended from the beginning of the first 10 successive conditioned responses through the last of the 5 presentations of the buzzer which elicited no adequate locomotor response. (During these 5 trials, the rat almost invariably sat still, although it might show head movements to the buzzer.) Conditioning and extinction were accomplished in one experimental period without removing the animal from the apparatus. For the 21 rats, the average period of extinction was 79 minutes, sigma 35 minutes, range 16–139 minutes.

Fig. 1 presents Vincent curves for the extinction of the present conditioned response.[9] Curve 1 shows

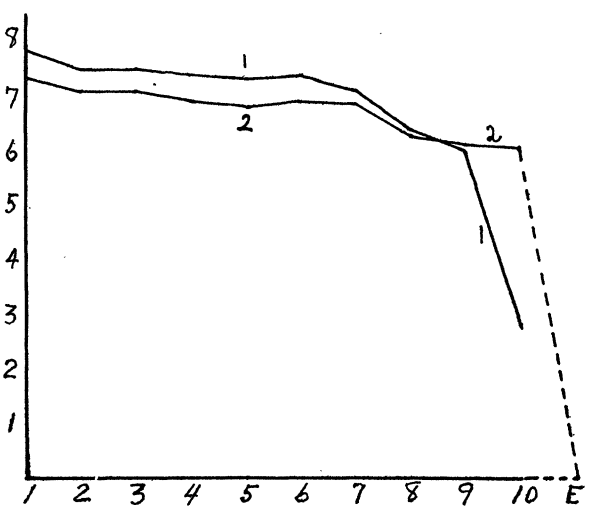


FIG. 1. Vincent curves for extinction of a conditioned locomotor response. The ordinate values are numbers of responses. The abscissa values represent tenths of the extinction period. *E*, for Curve 2, is the point at which no responses were made for 5 successive trials. The curves are described further in the text.

the average frequency of the conditioned response for tenths of the entire extinction period, *including* the last 5 trials when the rats sat still. Curve 2 excludes these last 5 trials and therefore represents the course of extinction up to the point where no response was made. The dotted portion of this curve indicates that, after the period of extinction, the rats suddenly ceased making locomotor responses to the buzzer. (The curves are derived from the 21 individual Vincent curves.) The unusual feature of these graphs is the sudden drop at the end, indicating the sudden elimination of the conditioned response. During the

[7] W. S. Hunter, *Brit. Jour. Psychol.* (in press).
[8] W. S. Hunter, SCIENCE, 81: 77–78, 1935.
[9] For comparable Vincent curves of the acquisition of the present conditioned response, see W. S. Hunter, *Jour. Exper. Psychol.* (in press).

period of extinction, the rats continued to run in response to the buzzer with a high degree of consistency until a point was reached where, relatively suddenly, no such responses were made. Inasmuch as the individual Vincent curves have essentially the same form found in the average curves, and inasmuch as the raw data reveal the same sudden termination of the conditioned response, the genuineness of the phenomenon seems well attested.

The extinction curves presented by Kleitman and Crisler and by Switzer are based on the magnitude of the conditioned response and not upon its frequency. Does the present conditioned locomotor response suffer a diminution in magnitude during the period of extinction so that the rat finally and gradually reaches a point where no movement is made to the buzzer? The present apparatus with its circular pathway permitted runs varying in magnitude from zero to an indefinitely large value. An examination of the records, however, shows that, although the lengths of the runs varied, there was no trend toward shorter and shorter runs. A curve relating the magnitude of the response to the amount of elapsed time would, therefore, have essentially the same form as the present curves, based on frequency of response. The suggestion is therefore apparent, from a comparison of the various curves found in the literature, that there is no one type of curve for extinction. Rather the character of the curve will depend upon many factors, including the type of response conditioned.

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## DISSOCIATION OF THE PYRAMIDAL AND EXTRAPYRAMIDAL FUNCTIONS OF THE FRONTAL LOBE

SECTION of one pyramidal tract below its last large supra-segmental connection with the pons produces in cats a syndrome of deficit describable either as the specific reactions lost or impaired, or as a depression of phasic activity in general; or as a loss of excitation at the final moto-neurones in the cord. Spasticity, or other evidence of release, is absent. Stimulation of the motor cortex either immediately or months after such a section demonstrates the preservation within that cortex of inhibition, effective on tonic or clonic states present in the limbs, together with the abolition of the familiar motor function. An extrapyramidal type of motor activity is at the same time uncovered.

Repetition of this lesion in rhesus monkeys produces a similar, though graver syndrome of deficit, again without spasticity. And again, stimulation of the cortex brings inhibition to bear on activity present in the limbs after destruction of the characteristic motor responses of the precentral gyrus. In the monkey, however, this inhibition is not confined, as in the cat, to the immediate motor region but is exercised by motor, premotor and prefrontal cortex, and from the second of these, most vigorously. From this region, for instance, tonic closure of the fingers into a grasp is most easily released. Moreover, although the fine type of movement characteristic of stimulation of the precentral gyrus is totally abolished by the lesion, the so-called adversive movements survive, and can be elicited not only from the premotor region but from the precentral and postcentral gyri, as well. Furthermore, after section of one or both pyramidal tracts at the level of the trapezoid body, with or without time for degeneration, epileptiform convulsions are easily set in train by stimulation of the motor, premotor and prefrontal regions, and even of spots in the parietal lobe. These involve all four limbs and face, show typical progression, tonic and clonic phases and after-exhaustion, resembling in essentials the clinical Jacksonian seizure.

One may conclude, therefore, that pyramidal and extra-pyramidal functions of the motor cortex and adjacent regions may be dissociated by pyramid section. The rapidly executed, fairly discrete movements, long familiar from cortical stimulation, are thus demonstrated to be mediated exclusively by the cortico-spinal tract. On the other hand, the integrity of this tract is not necessary to the exhibition of the larger movements called adversive, nor to the exercise of the very important inhibitory function of the cortex. Consequently, these, together with the epileptiform convulsions elicited, represent extrapyramidal activities of the cerebral cortex.

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## THE NATURE OF THE BARBITURATE–PICROTOXIN ANTAGONISM[1]

MALONEY, Fitch and Tatum[2] and Maloney and Tatum[3] have shown that picrotoxin is a very effective antidote in acute barbiturate poisoning. We have had ample occasion to confirm their data in animals poisoned with large doses of intravenously administered barbiturates. Quoting only extreme cases, the results in Table 1 were obtained:

To a number of dogs and rabbits, we administered the minimum anesthetic doses of different barbiturates, waited for the onset of anesthesia and then recorded

[1] From the Department of Pharmacology and Materia Medica, Georgetown University, School of Medicine, Washington, D. C.

[2] Maloney, Fitch and Tatum, *Jour. Pharmacol. Exper. Therap.*, 41: 465, 1931.

[3] Maloney and Tatum, *Jour. Pharmacol. Exper. Therap.*, 44: 337, 1932.